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A Theory of Capital Structure Relevance under Imperfect Information

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ABSTRACT

Firms raise debt and equity capital to finance a positive net present value project in perfectly competitive capital markets; firm insiders know the function generating the random firm cash flow but potential capital suppliers do not. Taking into account the incentives of insiders to misrepresent their firm type, capital suppliers attempt to design financing mixes of debt and equity that eliminate the adverse incentives of insiders and correctly price securities. Necessary conditions for a costless separating equilibrium are developed to show that the amount of debt used by a firm is monotonically related to its unobservable true value.

STIGLITZ [19] AND FAMA [5] DEMONSTRATE that the Modigliani-Miller [10] capital structure irrelevance theorem holds under a fairly general set of assumptions. One of these assumptions is that investor expectations of the returns of individual firms are independent of their capital structures. This paper introduces asymmetric information into an otherwise perfect, Modigliani-Miller world and develops a signaling equilibrium in which investor expectations about individual firms do depend upon the capital structures of the firms.[1]

In existing equilibrium models of markets with asymmetric information, such as Spence's [17] labor market, Rothschild and Stiglitz's [15] insurance market, or Leland and Pyle's [9] financial structure model, the sellers of higher quality products (higher quality labor, better insurance risks, or more valuable securities) incur some deadweight loss, since buyers are unable to distinguish quality without a signal from the seller; to prevent low quality sellers from sending a misleading signal, the signal must be costly. This paper describes a costless signaling equilibrium, in which sellers incur no deadweight losses and are as well off as they would be in a world of symmetric information. This equilibrium is not subject to the instability problems which may exist in the costly signaling equilibria.[2]

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[1] Other models have utilized other imperfections to demonstrate capital structure relevance. For example, Rubinstein [16] and Stiglitz [18] segment the market by tastes and beliefs, respectively, to develop debt/equity relevance. Many authors have used taxes and bankruptcy costs; Kraus and Litzenberger [8] is one example. Myers [11] combines moral hazard in firms' investment decisions with corporate taxes to show capital structure relevance. Jensen and Meckling [7] and Titman [20] use monitoring/bonding and liquidation costs, respectively, to derive optimal capital structure. A recent survey is provided by Chen and Kim [4].

[2] A costly signaling equilibrium may be unstable if there exists some pooling offer that is profitable to the buyer and that *all* sellers prefer to the signaling contracts. A pooling offer is a purchase offer at a single price corresponding to the price of the average quality product in the market; thus, in a

Investors are assumed to be unable to distinguish between firms of different value in the absence of a signal: the signal considered here is the choice of capital structure by the firm. This signal involves no welfare cost since, as Modigliani-Miller have shown, the choice of firm capital structure has no implications for the feasible opportunity set of investors. Such costless signals have been described as "nondissipative."[3]

The model here is similar to that of Ross [13, 14] in that both achieve a nondissipative or costless signaling equilibrium. However, Ross's model, like all previous nondissipative models, relies on the use of a *contingent* contract which makes the reward to the signaler depend not only on his signal, but also on some, perhaps imperfect, ex-post observation of the unknown feature being signaled. The model here derives a nondissipative result *without* the use of a contingent contract.

The Leland-Pyle [9] model does not employ contingent contracts and the resulting equilibrium is dissipative. The model here is similar to that of Leland-Pyle in that insider investors know the firm value, have control of the financing decision of the firm, and retain equity in the firm. It differs from the Leland-Pyle model in two important ways: first, Leland-Pyle assume that the insiders' signal, their equity holding of their own firm, is costly because of a loss of diversification. The model here assumes that insiders can alter their investment in the equity of the firm costlessly because of the existence of traded securities which are substitutes for the equity of the firm; by shorting these substitute securities, insiders can eliminate the diversification costs of their holdings.[4]

The model is also distinguished from that of Leland-Pyle in its treatment of borrowing by the firm. Leland-Pyle assume that all debt is *riskless*, so that the present value of the debt repayment promise of a firm is known and is independent of the firm making the promise. They are able to show that α, the proportion of equity investment retained by insiders, and firm value, are positively related. Since α and the amount of riskless debt sold by the firm are also positively related, they establish an *indirect* link between firm value and the amount of firm borrowing. The model here, on the other hand, assumes that all debt is *risky*, so that the present value of a given debt repayment promise does depend on the characteristics of the issuing firm. As a result, the signaling equilibrium directly involves the amount of risky debt sold by a firm.

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pooled equilibrium, high quality sellers receive too low a price for their product and subsidize low quality sellers who receive too high a price.

The pooled equilibrium will be preferred by all to the signaling equilibrium if the subsidization cost of pooling incurred by the high quality sellers is less than the cost of signaling their true quality in the signaling equilibrium; this will be true, for example, if the proportion of low quality sellers in the market is small.

However, Riley [12] for example, demonstrates that the pooled solution is not a Nash equilibrium since a buyer can always find a price offer that high quality sellers prefer and low quality sellers do not prefer to the pooled solution. In this situation there is no Nash equilibrium.

[3] See Bhattacharya [3] for a summary of the nondissipative equilibrium.

[4] This type of assumption on the existence of risk classes is used by Modigliani and Miller [10] in the derivation of their capital structure irrelevance result. A simple example is a complete (Arrow-Debreu [2]) market.

In the model developed below, insiders know both the true value of their firm, and the value of any given debt repayment promise made by the firm, while capital suppliers know neither. As a result, insiders can potentially profit by selling overpriced securities. For example, if insiders know that the equity of their firm is underpriced and the debt of their firm is overpriced, they can profit by issuing more debt and less equity to finance the required investment. Such a possibility will in general lead to market breakdown.[5] This eventuality is avoided here by a restriction on the joint distribution of firm value and credit risk: high value firms have less valuable, more risky, debt than do low value firms with the same promised debt repayment. As a result, a firm which represents itself as being of high value benefits by realizing a high price for its shares; on the other hand, it can sell debt only at a low price. Under certain conditions, capital suppliers, by offering only a restricted menu of acceptable debt-equity combinations, are able to eliminate the incentive of firm insiders to misrepresent the characteristics of their firm, and indeed are able to identify the characteristics of a firm from the particular debt-equity financing combinations chosen.

Section I develops the basic model and derives the symmetric information equilibrium. In Section II, the information asymmetry is introduced; this changes the incentives of insiders, who are tempted to misrepresent the characteristics of their firms. Necessary conditions are developed for a fully revealing, costless signaling equilibrium in which the incentive for misrepresentation is eliminated. Section III provides a numerical example, and Section IV is a brief summary and comment on model extensions and revisions.

I. The Perfect Information Model

Consider an economy in which each firm consists of a single one-period valuable project which requires financing. Each project exhibits decreasing returns and the optimal investment amount is the same for all projects. Financing for the projects is available from perfectly competitive debt and equity capital markets. Lenders purchase pure discount bonds which are subject to default risk, while outside equity capital is provided in return for a promise of a proportion $1 - \alpha$ of the aggregate cash flow available to equity. Insiders retain the right to the remaining proportion α of the equity cash flow. Define

- F: the face value of debt, due at the end of the period
- L: the debt financing provided to the firm by lenders, equal to the present value of the promised payment, F
- S: the amount of equity financing provided by outsiders
- V: the gross present value of the project
- E: the market value of the equity of the firm after the financing is completed
- α: the proportion of the equity retained by insiders

The value of the firm, V, is assumed to be a concave function of total

[5] See Akerlof [1].

investment, $I = L + S$, and the optimal investment amount I is the same for all firms. I is determined by the value-maximizing condition $V'(I) = 1$ and, using the above definitions,

$$V = L + E \tag{1}$$

and

$$S + L = I \tag{2}$$

Given the investment decision I, insiders select the debt face value, F, in return for which lenders provide debt financing L. Outside equity financing in the amount $S = I - L$ is provided in return for a fraction $1 - \alpha$ of the equity, worth $(1 - \alpha)E$. Insiders retain the fraction α and competition ensures that the amount of the outside equity contribution, S, is equal to the value of the equity claim required by outsiders, $(1 - \alpha)E$, so that

$$\alpha = 1 - S/E \tag{3}$$

The financing decision of the firm is characterized by its choice of F: given F, L is set competitively. S is, then, the external equity financing requirement $S = I - L$, and the fraction of the equity to which insiders are entitled, $1 - \alpha$, is also determined competitively. It is assumed that a firm taking both debt and equity financing enters into the agreements simultaneously and is observed by both lenders and equity investors. This assumption ensures that both the debt and equity contracts for a firm reflect the same risk and value assessment of the project by lenders and investors.

Insiders choose F to maximize the value of their retained equity position. It follows from Equations (1) through (3) that the value of the retained equity, αE, is given by

$$\alpha E = V - I = NPV \tag{4}$$

where NPV is the net present value of the project. Thus, the value of the project to the insiders is independent of the financing mix, which is consistent with the Modigliani-Miller [10] capital structure irrelevance theorem. The following sections will show that if capital suppliers are imperfectly informed, the Modigliani-Miller result may not hold, and capital structure and firm value may be related.

II. Imperfect Information and Adverse Incentives

Assume now that insiders know the random function that will generate the project cash flow but that potential capital suppliers know only the distribution of functions across the economy. Each possible return generating function is referenced by an index, n, to be called the quality rating of the firm. Without knowing the quality rating for a given firm, the capital market cannot arrive at the correct prices for debt and equity securities, $L(n, F)$ and $\alpha(n, F)$ for any F. This creates incentives for misrepresentation by insiders of the firm. The quality rating of the firm, which determines both its value and its risk, will affect the nature and the extent of these adverse incentives.

The value of the firm is assumed to be a continuous monotone function of n,

$V(n)$, and $L(n, F)$, the present value of debt with face value F, is also assumed to be continuous in n and F. The key assumption concerning $V(n)$ and $L(n, F)$ is

$$\underline{\text{Assumption (A.1)}} \quad \begin{aligned} &dV/dn < 0 \\ &\partial L/\partial n > 0 \\ &\partial L^2/\partial n \partial F \geq 0 \end{aligned}$$

over the range of debt used in the signaling equilibrium.[6]

Assumption (A.1) implies that adverse incentives of insiders differ in the debt and equity markets. Since $dV/dn = \partial E/\partial n + \partial L/\partial n$, (A.1) implies $\partial E/\partial n < 0$, so that high quality (high-n) firms have "safer" debt but are less valuable. Thus, high quality firms can benefit from misrepresentation in the equity market, while low quality (low-n) firms may benefit from misrepresentation in the debt market. A firm that claims to be of higher quality than it actually is raises debt on overly favorable terms, but the equity it sells will be undervalued. Therefore, any benefit from claiming a higher quality depends upon the trade-off between the gains and losses to misrepresentation in the two segments of the capital market.

Since capital suppliers are able to observe F but not n, the amount of debt financing, l, they are willing to provide in return for a given promised debt repayment, F, is a function only of F, $l(F)$. Similarly, the share of the equity demanded by outside equity investors, $(1 - \alpha)$, in return for their contribution $S = I - l(F)$ is a function only of F; hence, we may write $\alpha = \alpha(F)$.

Insiders know the true value of both the firm's debt claim $L = L(n, F)$, and the value of their retained equity position $\alpha(F)[V(n) - L(n, F)]$. They choose F to maximize this value:

$$\text{MAX}_F \alpha(F)[V(n) - L(n, F)] \tag{5}$$

For each possible firm quality n, the optimal choice of F by insiders, $F^*(n)$, is determined by the first-order condition

$$(d\alpha/dF)[V(n) - L(n, F)] - \alpha(F)(\partial L/\partial F) = 0 \tag{6}$$

The second-order condition is

$$T \equiv (d^2\alpha/dF^2)[V(n) - L(n, F)] - 2(d\alpha/dF)(\partial L/\partial F) - \alpha(F)(\partial^2 L/\partial F^2) < 0 \tag{7}$$

A costless signaling equilibrium implies that insiders of a firm of quality n receive the net present value of the firm so that, using Equation (4) and noting that $E(n, F) = V(n) - L(n, F)$

$$\alpha(F^*(n))[V(n) - L(n, F^*(n))] - [V(n) - I] = 0 \tag{8}$$

$F^*(n)$ is the optimal value F for insiders in a firm of quality n, as determined by Conditions (6) and (7).

Equations (6), (7), and (8) describe a costless signaling equilibrium in which

[6] Only sign $(dV/dn) = -\text{sign}(\partial L/\partial n)$ is necessary; we choose $dV/dn < 0$ as the convention. $\partial^2 L/\partial n \partial F \geq 0$ is sufficient, but not necessary, as seen below. However, the analysis will show that $\partial L/\partial n = 0$ is *not* allowable; all debt must be risky. The case of dV/dn and $\partial L/\partial n$ having the same sign is discussed in the concluding section.

the value-maximizing decisions of insiders determine $F^*(n)$, and the market correctly interprets this signal according to (8). Our object is to determine the conditions on the exogenous valuation functions $V(n)$ and $L(n, F)$ which are necessary for this costless signaling equilibrium to obtain. We shall first show that for incentive compatibility (i.e., Conditions (6) and (7)) it is necessary that low quality (i.e., high risk) firms issue more debt than do low risk firms ($dF^*(n)/dn < 0$). Then, eliminating $\alpha(F)$ between Conditions (6) and (8), we shall obtain an implicit equation for $F^*(n)$ involving only the exogenous functions $V(n)$ and $L(n, F)$. Combining this equation with the condition $dF^*/dn < 0$ yields the necessary condition on these valuation equations.

To show that Conditions (6) and (7) imply that $dF^*/dn < 0$, we take the total differential of the first-order condition (6)

$$\left[\left(\frac{d^2\alpha}{dF^2}\right)(V-L) - 2\frac{d\alpha}{dF}\frac{\partial L}{\partial F} - \alpha\left(\frac{\partial^2 L}{\partial F^2}\right)\right]\frac{dF}{dn} = \frac{d\alpha}{dF}\left(\frac{\partial L}{\partial n} - \frac{dV}{dn}\right) + \alpha\left(\frac{\partial^2 L}{\partial n \partial F}\right) \quad (9)$$

The right-hand side of (9) is positive,[7] and the bracketed term on the left-hand side is negative by the second-order condition (7). This implies $dF^*/dn < 0$.

To eliminate the endogenous function $\alpha(F)$, we take the total differential of Equation (8) with respect to n and use (6) to obtain

$$\alpha[F^*(n)] = (dV/dn)/(dV/dn - \partial L/\partial n)^8 \quad (10)$$

Substituting for $\alpha(F)$ from (10) into (8) yields an implicit equation for $F^*(n)$ in terms of the exogenous functions $V(n)$ and $L(n, F)$:

$$(V(n) - I)/(V(n) - L(n, F^*(n))) = (dV/dn)/(dV/dn - \partial L/\partial n) \quad (11)$$

Taking the total differential of (11) with respect to n yields

$$\frac{dF^*}{dn} = -\frac{(I-L)d^2V/dn^2 + (V-I)(\partial^2 L/\partial n^2)}{(V-I)\partial^2 L/\partial n \partial F - (dV/dn)(\partial L/\partial F)} < 0 \quad (12)$$

The denominator of (12) is positive by Assumption (A.1); therefore, for dF^*/dn to be negative, it is necessary that the numerator be positive. Using the fact that $\alpha = (V-I)/(V-L)$, this necessary condition for incentive compatibility, may be re-expressed as

$$(1-\alpha)(d^2V/dn^2) + \alpha(\partial^2 L/\partial n^2) > 0 \quad (13)$$

One interpretation of Condition (13) follows from noting that, for a given F, (13) is $\partial^2 O(n, F)/\partial n^2 > 0$ with $O(n, F) = V(n) - \alpha(F)E(n, F)$ defined as the true value of all of the claims of outsiders against the firm, which in equilibrium is equal to I. Since Equation (10) implies that $\partial O/\partial n = 0$ in equilibrium, (13) provides that the true value of the claims of outsiders is convex in n; the exogenous functions $V(n)$ and $L(n, F)$ allow outsiders to construct contracts $\{\alpha(F), l(F)\}$ such that any misrepresentation of a firm by insiders will be profitable to the outsiders and so, by definition, costly to the insiders of the firm. The result is a costless, fully revealing equilibrium.

[7] See Assumption (A.1) and note that $d\alpha/dF > 0$ is required by the first order condition.

[8] The constraint $0 \leq \alpha(n, F) \leq 1$ implies that sign $(dV/dn) = -\text{sign}(\partial L/\partial n)$.

III. An Example

Consider an Arrow-Debreu [2] two-state economy, with

$X_s(n)$: the end-of-period cash flow to a firm of type n in state s
P_s: the market value of one dollar to be received in state s
$V(n) = \sum_s P_s X_s(n)$: the market value of a firm of type n.

Assume $X_1(n) < X_2(n)$ for all n, so that state 1 is the "low payoff" state. In order to satisfy Assumption (A.1) it must be that $dX_1(n)/dn > 0$ so that $\partial L/\partial n > 0$; then in order for $dV/dn < 0$ it must be that $dX_2(n)/dn < 0$.[9]

Table I

An Arrow-Debreu Example

$P_1 = .4$	$X_1(n) = .2n^2$	$V(n) = 50 - 4n + .08n^2$
$P_2 = .5$	$X_2(n) = 100 - 8n$	$I = 15$

Table I provides a simple example that satisfies the necessary condition (12). Insiders choose F to maximize

$$\alpha(F)[V(n) - L(n, F)] = \alpha(F)P_2[X_2(n) - F]$$

To develop the equilibrium contract schedule $\alpha(F)$, we first use the necessary condition (10) to determine α as a function of n:

$$\alpha(n) = 1 - .04n \tag{14}$$

Then $L(n, F^*(n))$ may be determined from the requirement expressed by Equation (8) that the equilibrium value of the equity retained by the insiders be equal to the NPV of the firm. Substituting in (8) for $\alpha(n)$ from (14) and for $V(n)$ from Table I yields

$$L(n, F^*(n)) = \frac{15 - 2n + 16n^2 - .0032n^3}{1 - .04n} \tag{15}$$

But market equilibrium requires that $L(n, F) = P_1X_1(n) + P_2F$; combining this with (15) provides

$$F^*(n) = \frac{30 - 4n + .16n^2}{1 - .04n} \tag{16}$$

Finally, eliminating the unobservable n between (14) and (16), the equilibrium contract schedule is

$$\alpha(F) = .5 + .005[F + (F^2 + 200F - 2000)^{1/2}] \tag{17}$$

It may be verified that $F^*(n)$ in (16) satisfies (6) and that the second-order condition (7) is satisfied by (17) along the equilibrium choice function (16); in addition, (8) is satisfied by virtue of its use in the derivation of Equation (15) from the necessary condition (14).

[9] If the debt is risky, default must occur in state 1 so that

$$L(n, F) = P_1X_1(n) + P_2F$$

and

$$V(n) - L(n, F) = P_2[X_2(n) - F]$$

Table II

Data for the Example

n	$V(n)$	$NPV(n)$
1	46.08	31.08
2	42.32	27.32
3	38.72	23.72
4	35.28	20.28

Table III

Value of Insider Holdings under Different Contracts: $\alpha[V(n) - L(n, F)]$

Firm Type:	CONTRACT $\alpha(1) = .96$ $F^*(1) = 27.25$	$\alpha(2) = .92$ $F^*(2) = 24.61$	$\alpha(3) = .88$ $F^*(3) = 22.09$	$\alpha(4) = .84$ $F^*(4) = 19.72$
1	31.08*	31.00	30.76	30.36
2	27.24	27.32*	27.24	27.00
3	23.40	23.64	23.72*	23.64
4	19.56	19.96	20.20	20.28*

* = Equilibrium contract.

Table II contains data for a numerical example with four firm types. Table III exhibits the value of insider holdings under each of four contract offers derived from equilibrium equations (14) and (16). For example, if capital suppliers offer a contract for firm 1 with $F = 27.25$, $l = 13.705$, and $\alpha = .96$,[10] and the insiders of firm type 2 consider taking the contract, they would receive only

$$\alpha[V(n) - L(n, F)] = (.96)[42.32 - 13.945] = 27.24^{11}$$

while, if they choose the $\alpha = .92$ contract designed for them, they receive

$$\alpha[V(n) - L(n, F)] = (.92)[42.32 - 12.624] = 27.32$$

which is the perfect information result. Calculating the other entries in Table III in the same way demonstrates that the insiders of each firm type select a contract designed for that type and the resulting values of the equity retained by insiders are the perfect information net present values; any misrepresentation leaves insiders worse off than the self-selecting policy.

Since I is identical for all n and $dF^*/dn < 0$, the signaling equilibrium has higher risk firms (low n) taking on more debt and low value firms (high n) using more equity financing; as expected, each firm type is attracted to that market in which it could be overvalued. Or, since $dV/dn < 0$, the equilibrium exhibits higher value firms taking on larger amounts of debt.[12]

In the discrete-n case, as demonstrated by the numerical example, firms retain some financing flexibility, in that the Modigliani-Miller proposition still holds, but only over a limited range of debt financing. This result is consistent with the traditional corporate finance literature which claims that the cost of capital of a firm is a pan-shaped function of the debt ratio, allowing some flexibility in the optimal capital structure choice.

[10] $l = P_1X_1(1) + P_2F = (.4)(.2) + (.5)(27.25) = 13.705$ and $\alpha = (V(1) - I)/(V(1) - 13.705) = .96$.

[11] $L(2, 27.25) = P_1X_1(2) + P_2F = (.4)(.8) + (.5)(27.25) = 13.945$.

[12] No conclusion can be drawn, however, concerning the cross-sectional distribution of the ratio of debt to the market value of the firm since the theory only provides that both are decreasing in n.

IV. Concluding Comments

This paper derives a separating equilibrium involving capital structure relevance in an asymmetrically informed, but otherwise perfect, capital market. Assuming a positive correlation between firm value and credit risk across firms, the Modigliani-Miller capital structure irrelevance theorem is refuted; in equilibrium, riskier, more valuable firms have larger amounts of debt financing. Leland-Pyle also conclude that firm value and the amount of debt is positively correlated; however, all debt in their model is riskless, while in the model developed here, all debt is risky.

The signaling equilibrium is costless; there are no potential contracts, currently not offered, which are perceived by Nash agents to be preferable or profitable to the equilibrium set of contracts. The potential instability exhibited by the Spence [17] and Rothschild-Stiglitz [15] costly signaling equilibria, as described by Riley [12], does not exist.

The critical assumption is that firm value is positively related to credit risk, (A.1). Under (A.1), insiders face opposing incentives in debt and equity markets: if a firm can sell overvalued debt, its equity will be undervalued. This trade-off allows for the possibility of capital suppliers finding contracts which have negative net benefits to misrepresenting for all firms.

Assumption (A.1) is in fact necessary for a costless signaling equilibrium. Suppose that, contrary to (A.1), values and credit risks of firms are negatively related. Then, a firm with lower value is also riskier to lenders; the insiders of such a firm will always want to misrepresent their firm as being more valuable and safer no matter what debt/equity mix the more valuable, safer firm is offered. Thus, no costless contract can be offered to the more valuable, safer firm. However, a costly separating equilibrium may exist in which the more valuable, safer firm is given a smaller than allocationally efficient financing contract with $S + L < I$ by a sufficient amount to discourage misrepresenting by the less valuable, riskier firm. In addition to inefficient investment, this equilibrium may contain corner solutions for the debt ratios, depending upon the distribution of firm quality across the economy.[13] Because the separating solution is costly to insiders, the negative risk-value case is subject to the same instability problems as the Rothschild-Stiglitz and Spence equilibria.

Whether firms in a particular population have positively correlated values and credit risk is an empirical question; the model developed here has examined necessary conditions for a costless separating solution when NPV and credit risk are positively related. The resulting equilibrium with capital structure relevance exists without reliance on other market imperfections such as taxes, bankruptcy costs, or monitoring and bonding costs.

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[13] See Heinkel [6] for the derivations of such equilibria.

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